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Development of Reconfigurable Analog and Digital Circuits for Plasma Diagnostics Measurement Systems

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In long pulse discharge tokamak, a large number of diagnostic channels are being used to understand the complex behavior of plasma. Different diagnostics demand different types of analog and digital processing for plasma parameters measurement. This leads to variable requirements of signal processing for diagnostic measurement. For such types of requirements, we have developed hardware with reconfigurable electronic devices, which provide flexible solution for rapid development of measurement system. Here the analog processing is achieved by Field Programmable Analog Array (FPAA) integrated circuit while reconfigurable digital devices (CPLD/FPGA) achieve digital processing. FPAA's provide an ideal integrated platform for implementing low to medium complexity analog signal processing. With dynamic reconfigurability, the functionality of the FPAA can be reconfigured in-system by the designer or on the fly by a microprocessor. This feature is quite useful to manipulate the tuning or the construction of any part of the analog circuit without interrupting operation of the FPAA, thus maintaining system integrity. The hardware operation control logic circuits are configured in the reconfigurable digital devices (CPLD/FPGA) to control proper hardware functioning. These reconfigurable devices provide the design flexibility and save the component space on the board. It also provides the flexibility for various setting through software. The circuit controlling commands are either issued by computer/processor or generated by circuit itself.

Keywords: reconfigurable analog circuit, reconfigurable digital circuit, field programmable analog arrays, plasma diagnostics measurement, field programmable gate arrays, fpaa, fpga

1. Introduction

The time duration of tokamak discharge has been prolonged in accordance with the development of fusion research. In the next generation tokamak like SST-1 and ITER [1] the discharge time of the order of 1000 sec. is planned. At the same time demand for more no. of acquisition channels from different diagnostics is increasing. Various diagnostics demand different types of analog and digital processing for plasma parameters measurement. This leads to variable requirements of signal processing for diagnostic measurement. For such types of requirements, we have developed hardware with reconfigurable electronic devices, which provide flexible solution for rapid development of measurement system. Here the analog processing is achieved by Field Programmable Analog Array (FPAA) integrated circuit while reconfigurable digital devices (CPLD/FPGA) achieve digital processing. FPAA's provide an ideal integrated platform for implementing low to medium complexity analog signal processing. Recent trends in hardware design have seen a marked increase in the use of programmable devices such as CPLDs (Complex Programmable Logic Device) and FPGAs (Field Programmable Gate Arrays), and more recently field-programmable analog arrays (FPAA). Programmable devices reduce the time and cost of hardware prototyping. Design using field-programmable devices is automated through the use of sophisticated computer-aided design (CAD) tools, which synthesize circuits from schematic, high-level, or behavioral descriptions into usable hardware. This automated CAD flow reduces the need for detailed design expertise in developing working hardware and thus makes hardware design open to a greater number of users. These reconfigurable devices provide the design flexibility and save the component space on the board.

2. Reconfigurable Measurement system

The hardware design of reconfigurable measurement system is presented as block diagram in figure 1. The block diagram shows how various elements

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are connected with each other for achieving the following described functions:

- Signal conditioning of the sensor/transducer signal
- Configuring analog circuits in FPAA integrated circuit to achieve analog processing as per diagnostics requirements
- Analog to digital conversion
- Configuring digital circuits in FPGA integrated circuit to process on-board digital data for acquisition and control

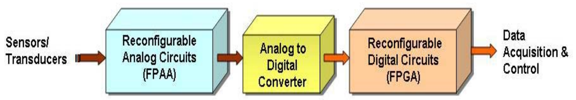

Fig. 1 Block Diagram of Measurement system using Reconfigurable devices

We have developed the reconfigurable measurement system for plasma diagnostics for variable requirements. Implementation and testing of our analog designs has been done through FPAA development board while digital processing has been achieved with in-house developed FPGA based CAMAC digitizer.

3. Reconfigurable Analog Circuits

Reconfigurable analog circuits have been implemented using FPAA device for variable analog signal processing requirements. A field programmable analog array is a powerful and flexible integrated circuit for quickly, efficiently, and accurately designing a wide variety of circuits, including multiple-pole filters and other related circuits. FPAAs may soon prove themselves in applications requiring fast and complex analog circuit prototyping and flexibility in the final analog circuit design. Design using field-programmable devices is automated through the use of sophisticated computer-aided design (CAD) tools, which synthesize circuits from schematic, high-level, or behavioral descriptions into usable hardware. Figure 2 shows schematic and simulation in the FPAA development software for our analog circuit configuration. We have configured the FPAA for various signals conditioning task like amplification, offset removal, filtering etc. For analog processing, we have tested various circuits like variable gain circuit, comparator, filter, wave rectifier etc. The advantage we get with these devices is that we can configure the circuits as per our diagnostics requirements. We can also simulate the circuit through software before placing actual circuit in FPAA device. With dynamic reconfigurability, the functionality of the FPAA can be reconfigured in-system by the designer or on the fly by a microprocessor. This feature is quite useful to manipulate the tuning or the construction of any part of the analog circuit without interrupting operation of the FPAA, thus maintaining system integrity.

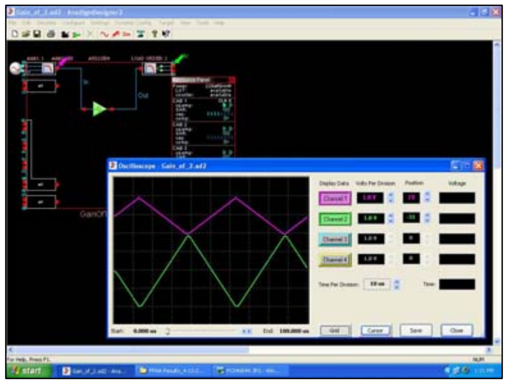

Fig. 2 Schematic and simulation in FPAA development software to configure analog circuit.

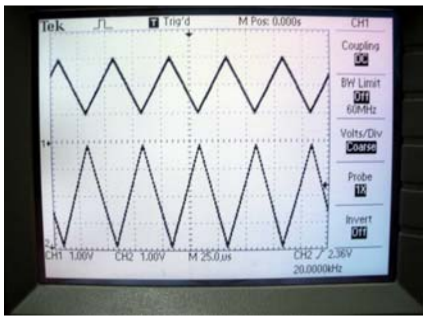

Fig. 3 Measured signal on oscilloscope of input and output of FPAA based amplification circuit

4. Reconfigurable Digital Circuits

Reconfigurable digital circuits have been implemented using FPGA device and analog to digital converter circuitry for on-board data processing requirements of data acquisition and control [2]. The designed module is a FPGA based CAMAC digitizer. The FPGA is used for all system module logic function and on-board data processing. The main aim to design this CAMAC module is to process the data, acquired from various channels, in real time and to output it for further action. The module can be used for monitoring, control and acquisition [3]. The real time processing has been implemented with VHDL hardware description language. The module can be configured to acquire data from up to eight channels with real time processing capability using VHDL code with FPGA as target device. The processed data can also be output through Digital to Analog Converter. VHDL code is a hardware description language for reconfigurable digital devices

(CPLD/FPGA). We can easily configure the digital logic and can verify the design though simulation before actual implementation in device. We have tested the circuit for various data processing algorithm like addition, multiplication etc.

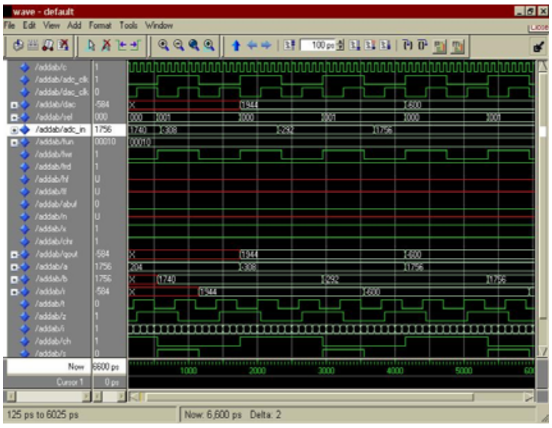

Fig. 4 Digital Design verification: VHDL code simulation.

5. Graphical User Interface

A user-friendly Graphical User Interface (GUI) has been developed with LabVIEW application software for acquisition through developed hardware. This provides a convenient display and analysis platform for acquired data. The main feature that distinguishes LabVIEW from other data acquisition application software is its highly modular graphical programming language and large library of mathematical and statistical functions.

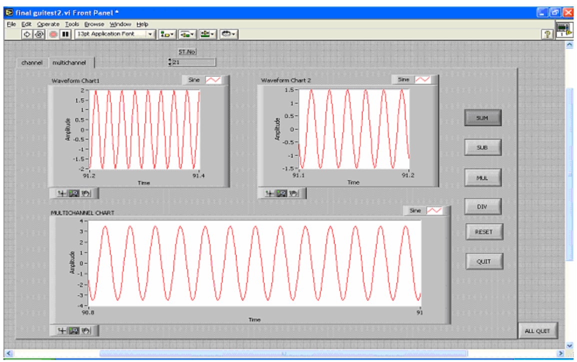

Fig. 5 GUI developed in LabVIEW for acquisition and to configure FPGA for various processing algorithms

The advantage of graphical programming is that the code is flexible, reusable, and self-documenting. Subroutines can be saved in a library and reused without modification in other programs. This dramatically reduces development time and enables researchers to develop or modify their own programs.

6. Results & Discussion

We have tested the developed reconfigurable analog and digital hardware for different analog signal conditioning circuits and digital signal processing algorithms. The developed CAMAC module has been tested in CAMAC data acquisition system with precise test and measurement equipments. The testing has been performed with GUI developed in LabVIEW application software. We have tested the DC performance as well as AC performance of hardware with utility developed in LabVIEW software. We have found the results quite satisfactory. These reconfigurable technologies may be quite useful, in future, for development of variable requirement plasma diagnostics measurement systems for different interfaces.

7. Acknowledgement

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